VII. ENVIRONMENTAL IMPACTS

This chapter describes the potential environmental impacts of the proposed regulation. The proposed regulation is intended to protect the health of California's citizens by reducing the exposure to the emissions from ocean-going vessel auxiliary engines. An additional consideration is the impact that implementation of the proposed regulation may have on the environment. Based upon available information, ARB staff has determined that no significant adverse environmental impacts should occur as the result of the proposed regulation. This chapter describes the potential impacts that the proposed regulation may have on air quality, water quality, and hazardous waste disposal.

A. Legal Requirements

The California Environmental Quality Act (CEQA) and ARB policy require an analysis to determine the potential environmental impacts of proposed regulations. Because ARB's program involving the adoption of regulations has been certified by the Secretary of Resources pursuant to Public Resources Code section 21080.5, the CEQA environmental analysis requirements may be included in the Initial Statement of Reasons (ISOR) for this rulemaking. In the ISOR, ARB must include a "functionally equivalent" document, rather than adhering to the format described in CEQA of an Initial Study, a Negative Declaration, and an Environmental Impact Report. In addition, staff will respond, in the Final Statement of Reasons for the regulation, to all significant environmental issues raised by the public during the public review period or at the Board public hearing.

Public Resources Code section 21159 requires that the environmental impact analysis conducted by ARB include the following:

- an analysis of reasonably foreseeable environmental impacts of the methods of compliance;
- an analysis of reasonably foreseeable feasible mitigation measures; and
- an analysis of reasonably foreseeable alternative means of compliance with the regulation.

Compliance with the proposed regulation is expected to directly affect air quality and potentially affect other environmental media as well. Our analysis of the reasonable foreseeable environmental impacts of the methods of compliance is presented below.

Regarding mitigation measures, CEQA requires an agency to identify and adopt feasible mitigation measures that would minimize any significant adverse environmental impacts described in the environmental analysis.

The proposed regulation is needed to reduce the risk from exposures to diesel PM as required by Health and Safety Code (H&SC) sections 39666 and to fulfill the goals of the Diesel Risk Reduction Plan. Alternatives to the proposed regulation have been discussed earlier in Chapter V of this report. ARB staff has concluded that there are no alternative means of compliance with the requirements of H&SC sections 39666 that would achieve similar diesel PM emission reductions at a lower cost.

B. Effects on Air Quality

The proposed regulation will provide diesel PM, NOx, and SOx emissions reductions throughout California, especially in coastal urban areas many of which are non-attainment for the State and federal ambient air quality standards for PM_{10}, $PM_{2.5}$ a and ozone.

Emission Reduction Estimates

For 2007 through 2009, the emission reductions resulting from the proposed regulation were estimated based on the proportion of auxiliary engines using heavy fuel oil, and the differences in the emissions between auxiliary engines using 2.5 percent heavy fuel oil and 0.5 percent marine gas oil. The sulfur levels for heavy fuel oil and marine gas oil represent the average sulfur contents for these fuels based on vessels visiting California ports based on the ARB's 2005 Ship Survey. (ARB, 2005). Auxiliary engines using distillate fuels would generally be unaffected by the proposed regulation until 2010.

For 2010 and later, when the emission limit based on the anticipated use of 0.1 percent sulfur marine gas oil is implemented, we estimated the emission reductions based on: (1) the proportion of auxiliary engines using heavy fuel oil, and the differences in the emissions between auxiliary engines using 2.5 percent heavy fuel oil and 0.1 percent marine gas oil; and (2) the proportion of auxiliary engines using distillate fuel, and the differences in the emissions between auxiliary engines using 0.5 percent marine gas oil and 0.1 percent marine gas oil.

The estimated reductions in PM emissions that would occur when switching from heavy fuel oil to distillate fuels result, in large part, from the lower sulfur content of distillate fuel, which reduces the formation of sulfate PM. In addition, the lower ash content and lower density of distillate fuel also contributes to lower PM emissions (EPA, 2002). The lower sulfur content of distillate fuel also directly contributes to lower SOx emissions. For example, lowering the sulfur content from 2.5 percent to 0.5 percent represents an 80 percent reduction in the sulfur content of these fuels, and results in an 80 percent reduction in SOx emissions. The lower nitrogen content of distillate fuels also results in a reduction in NOx emissions (EPA, 2002).

The emission factors used to estimate the emissions and emission reductions from auxiliary engines are discussed in detail in Appendix D. These emission factors are shown in Table VII-1 below. The estimated percent emission reductions from auxiliary engines that switch fuels are shown in Table VII-2 below. While these percent emission reductions represent our best estimates, we recognize that emissions test results for PM vary widely depending on the source of information.

Table VII-1: Estimated Emission Factors (g/kw-hr)

Pollutant	HFO @ 2.5% sulfur	MGO @ 0.5% sulfur	MGO @ 0.1% sulfur
NOx	14.7	13.9	13.9
SOx	11.1	2.1	0.4
PM	1.5	0.38	0.25

Table VII-2: Estimated Emission Reductions for Auxiliary Engines Switching from Heavy Fuel Oil to the Specified Distillate Fuels

Pollutant	Percent Reduction: HFO to MGO @ 0.5% Sulfur	Percent Reduction: HFO to MGO @ 0.1% Sulfur
NOx	6%	6%
SOx	80%	96%
PM	75%	83%

Table VII-3 below shows the auxiliary engine emissions within the 24 nautical mile boundary, which are subject to the proposed regulation. The emissions are grown uncontrolled from 2004 to 2020 based on the growth assumptions discussed in Appendix D.

Table VII-3: Projected Emissions from Auxiliary Engines within 24 Nautical Miles of California's Coastline

	Auxiliary Engine Emissions (Tons per Day)		
Year	PM	NOx	SOx
2004	3.0	34	22
2007	3.8	43	28
2010	4.6	52	34
2015	6.2	69	45
2020	8.7	95	64

The ARB staff estimates that implementation of the proposed regulation will result in immediate and substantial reductions in diesel PM, NOx, and SOx emissions, as shown in Table VII-4 below. Upon implementation in 2007, this represents about a 70 percent reduction in PM emissions from the baseline emissions subject to the regulation (emissions within the 24 nautical mile boundary). In addition, the proposed regulation will result in reductions in carbon dioxide (CO_2), a global warming gas. Specifically, the use of use of distillate marine fuels will result in about a 5 percent reduction in CO_2

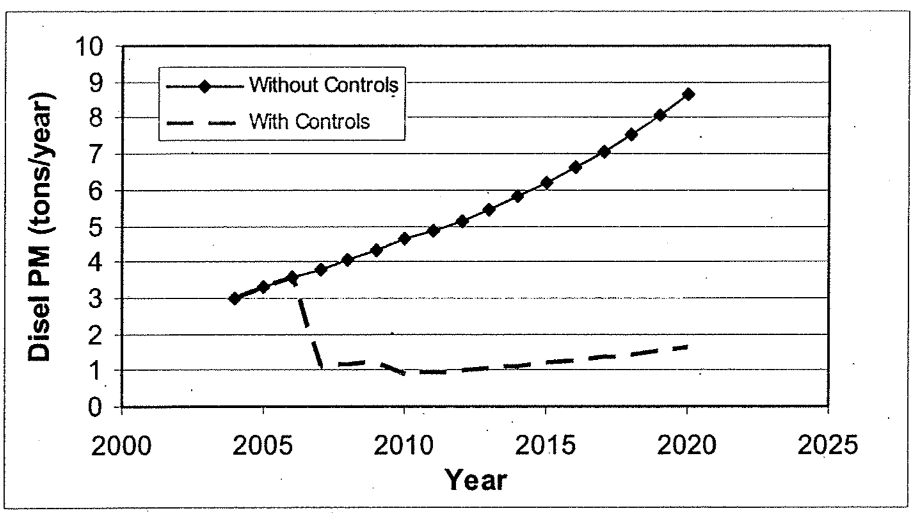
emissions compared with heavy fuel oil, and use of shore-side power would result in much greater percent reductions compared to the use of diesel auxiliary engines.

Table VII-4: Emission Reductions from Implementation of the Proposed Regulation

Year	Auxiliary Engine Emission Reductions (Tons per Day)		
	PM	NOx	SOx
2007	2.7	1.9	22
2010	3.7	2.3	32
2015	5.0	3.2	43
2020	7.0	4.4	61

Figure VII-1 illustrates how the diesel PM emissions from ship auxiliary engines within the 24 nautical mile boundary will grow with and without the proposed regulation. As shown, the growth in emissions would eventually negate the emissions reductions associated with the implementation of the proposed regulation.

Figure VII-1: Estimated Diesel PM Emissions in 24 nm Zone With and Without the Implementation of the Proposed Regulation



C. Estimating the Health Benefits Associated with the Reductions of Diesel PM Emissions

Reduced Ambient Particulate Matter Levels

A substantial number of epidemiologic studies have found a strong association between exposure to ambient particulate matter (PM) and adverse health effects. (ARB, 2002) For this report, ARB staff evaluated the impacts the proposed regulation would have on potential cancer risks and conducted a quantitative analysis of four potential non-cancer health impacts associated with exposures to ambient levels of directly emitted diesel PM.

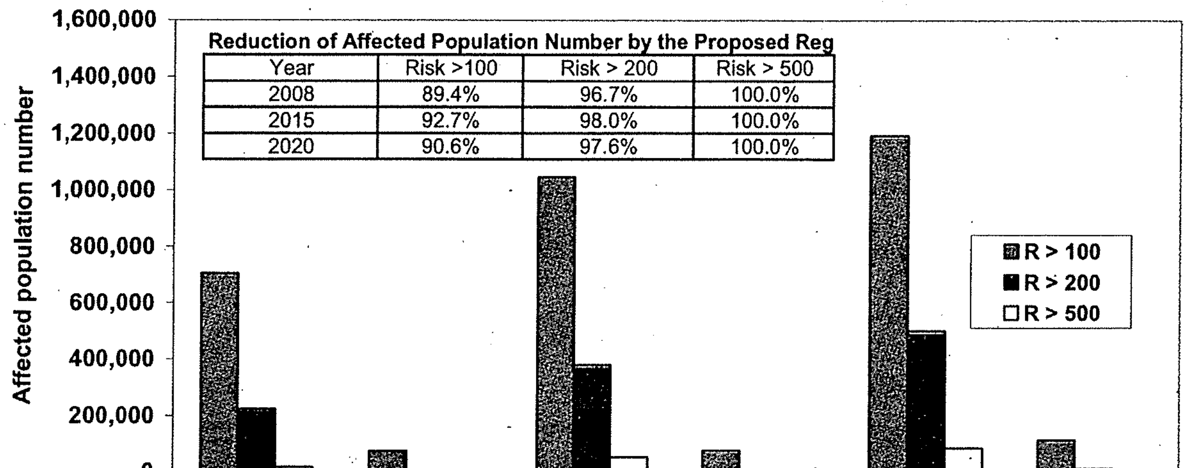
Reduction in Potential Cancer Risks

The reductions in diesel PM emissions that will result from implementation of the proposed regulation will reduce the publics exposures to diesel PM emissions and the potential cancer risks associated with those exposures. The ARB staff used the air dispersion model and model inputs developed for the POLA and POLB health risk assessment to estimate the reductions in potential cancer risk that would result in the area surrounding the ports of POLA and POLB from implementation of the proposed regulation. The ARB staff believes that the results from this analysis provide quantitative results for exposures around the Ports of Los Angeles and Long Beach and are generally applicable to other ports in California, providing a qualitative estimate for those areas.

To investigate the reductions in potential risks that will result as emissions from ocean-going vessel auxiliary engines decline, ARB staff used dispersion modeling and the projected 2008 and 2015 controlled and uncontrolled emissions inventories to estimate the ambient concentration of diesel PM emissions that result from the operation of cargo handling equipment at the Ports of Los Angeles and Long Beach in 2008 and 2015. The potential cancer risks from exposures to the projected controlled and uncontrolled 2008 and 2015 emissions were then estimated to determine how the potential risks will change. As shown in Figures VII-2 and VII-3, we expect a significant decline in the number of people exposed to high risk levels from cargo handling equipment emissions and the acres impacted as the proposed regulation is implemented.[5] Based on our analysis, which is summarized in Appendix K, we estimate that, in 2008, there will be a 70 percent reduction in the population-weighted average risk relative to uncontrolled risk levels in from ocean-going vessel auxiliary engine emissions and approximately a 78 percent reduction in 2015.

[5] Because the isopleths for risk levels at 10 in a million were outside the modeling domain, we are not able to quantify the expected regulatory impact on this risk level. However, we believe that the risk levels greater than 10 in a million are also significantly reduced.

Figure VII-2: Comparison of Affected Population Numbers With and Without the Proposed Ship Auxiliary Engine Fuel Regulation for the Years 2008 and 2015

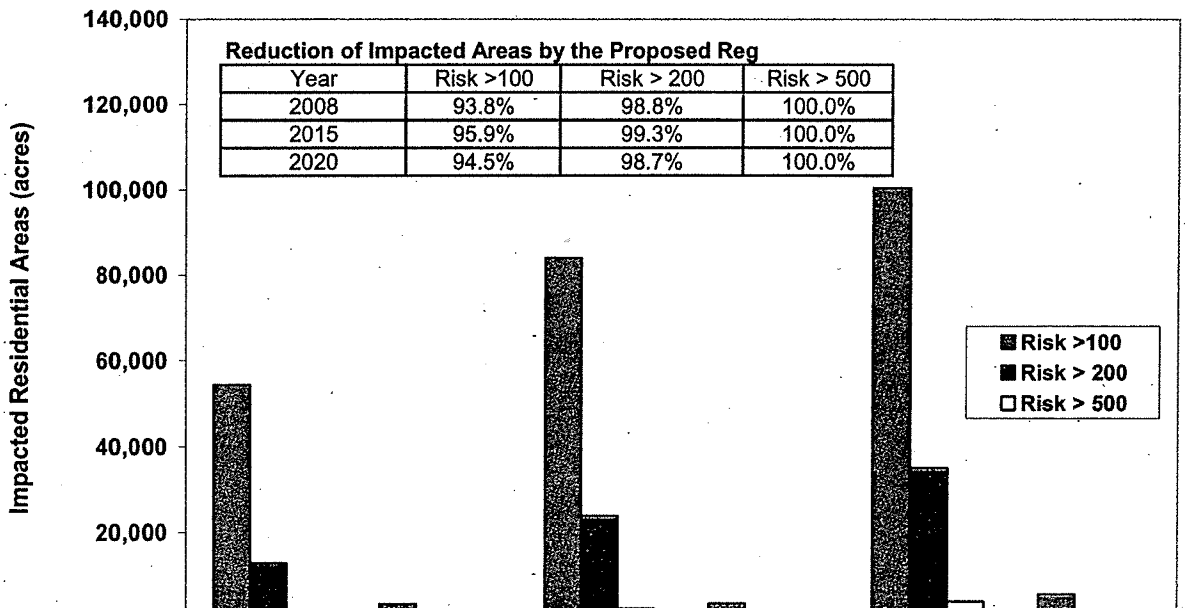


Reduction of Affected Population Number by the Proposed Reg

Year	Risk >100	Risk > 200	Risk > 500
2008	89.4%	96.7%	100.0%
2015	92.7%	98.0%	100.0%
2020	90.6%	97.6%	100.0%

	2008 without Reg	2008 with Reg	2015 without Reg	2015 with Reg	2020 without Reg	2020 with Reg
R > 100	704,995	74,630	1,045,555	75,870	1,191,262	112,440
R > 200	223,561	7,464	379,237	7,570	499,675	12,100
R > 500	18,885	0	52,277	0	84,760	0

Figure VII-3: Comparison of Impacted Residential Areas With and Without the Proposed Ship Auxiliary Engine Fuel Regulation for the Years 2008 and 2015



Reduction of Impacted Areas by the Proposed Reg

Year	Risk >100	Risk > 200	Risk > 500
2008	93.8%	98.8%	100.0%
2015	95.9%	99.3%	100.0%
2020	94.5%	98.7%	100.0%

	2008 without Reg	2008 with Reg	2015 without Reg	2015 with Reg	2020 without Reg	2020 with Reg
Risk >100	54,333	3,361	83,838	3,440	100,255	5,535
Risk > 200	12,909	158	[illegible]	168	34,852	455
Risk > 500	811	0	2,273	0	3,973	0

Non-cancer Health Impacts and Valuations

To determine the impacts from the proposed regulation on non-cancer health endpoints, ARB staff used the methodology described previously in Chapter IV but evaluated the change in ambient PM levels that are expected due to implementation of the proposed regulation. This analysis shows that the statewide cumulative impacts of the emissions reduced through this regulation from year 2007 through 2020 are approximately:

- 520 premature deaths (260 to 810, 95% CI)
- 14,000 asthma attacks (3,400 to 24,000, 95% CI)
- 120,000 work loss days (103,000 to 140,000, 95% CI)
- 650,000 minor restricted activity days (530,000 to 770,000, 95% CI)

Value of Non-Cancer Effects

Premature Death: The U. S. EPA has established $6.3 million (in 2000 $) for a 1990 income level as the mean value of avoiding one death. (EPA, 2003) As real income increases, people may be willing to pay more to prevent premature death. The U.S. EPA further adjusted the $6.3 million value to $8 million (in 2000 $) for a 2020 income level. Assuming that real income grew at a constant rate from 1990 and will continue at the same rate until 2020, we adjusted the value of avoiding one death for income growth. We then updated the value to 2005 dollars and discounted values of avoiding a premature death in the future back to the year 2005. The U.S. EPA's guidance of social discounting recommends using both three and seven percent discount rates. (EPA, 2000)

Based on these rates, the total valuation of the avoided premature deaths is about $3 billion at seven percent discount rate, and $4 billion at three percent discount rate. Based on using the annual avoided deaths as weights, the weighted average value of reducing a future premature death, discounted back to the year 2005, is around $5 million at seven percent discount rate, and $7 million at three percent. These are point estimates. The uncertainty in the mortality estimates is on the order of 50 percent, so the valuation estimates are likewise uncertain, by plus-or-minus about 2 billion dollars.

Non-Mortality Health Effects: To estimate the values of certain non-mortality health effects, we use U.S. EPA valuations, updated to 2005 dollars, for avoiding non-fatal health effects (EPA, 2003):

- $49 for acute asthma attack
- $180 for work loss day
- $58 for minor restricted activity day (MRAD)

The expected reduction in acute asthma attack is about 14,000 cases. The total valuation is about $0.4 million using a seven percent discount rate, and $0.6 million using a three percent discount rate.

For the 120,000 avoided work loss days, their valuation is about $14 million using a seven percent discount rate, and $18 million using a three percent discount rate. For the 650,000 avoided MRAD, their valuation is about $24 million using a seven percent discount rate, and $31 million using a three percent discount rate.

Reduced Ambient Ozone Levels

Emissions of NOx and ROG are precursors to the formation of ozone in the lower atmosphere. Exhaust from diesel engines contributes a substantial fraction of ozone precursors in any metropolitan area. Therefore, reductions in NOx and ROG from diesel engines would make a considerable contribution to reducing exposures to ambient ozone. Controlling emissions of ozone precursors would reduce the prevalence of the types of respiratory problems associated with ozone exposure and would reduce hospital admissions and emergency visits for respiratory problems.

D. Reasonably Foreseeable Environmental Impacts as a Result of Potential Compliance Methods

The proposed regulation has two possible compliance routes, the fuels option, and the alternative compliance plan (ACP). Both options have potential environmental impacts.

The fuels option is expected to be the most common compliance method. A vessel complying with the regulation through this option may need to increase its storage capacity for distillate fuel by adding a tank or segregating an existing tank. Adding a fuel tank could potentially displace some cargo space, increasing the amount of fuel burned and emissions per a given amount of cargo transported. However, ARB staff does not expect a significant impact from the potential loss of cargo space. Most vessels already have multiple fuel tanks and are thereby able to accept multiple fuels. Specifically, according to the Survey, only about 10 percent of vessels would require modifications to use distillate fuels to comply with the proposed regulations (such as increasing their storage capacity for distillate fuels). Since some vessels reported the need for modifications not related to fuel storage, less than 10 percent of vessels would need to increase their storage capacity for cleaner burning fuels. For the minority of vessels that need to increase their fuel storage capacity, many may be able to segregate an existing tank as an alternative to adding a new tank. Finally, others will be able to add a new tank without impacting cargo capacity.

The use of a different fuel for California may also require increased fuel deliveries to the ship. This could potentially increase the possibility of fuel spills. However, refueling personnel can lower the possibility of fuel spills with training, and by following standard refueling operating procedures.

The ACP provides for a range of technologies that could be used to comply with the proposed regulation. Listed below are some potential technologies that could be used to comply with the proposed regulation. The ACP provisions are described in more detail in Chapter V.

Selective Catalytic Reduction (SCR)

The heart of the SRC system is the catalyst. The reaction converting NOx to nitrogen and water occurs on the surface of the catalyst. NOx compounds must come into contact with the catalyst in order to be converted. Modern catalysts are usually made in the form of honeycomb structures.

Many catalysts materials contain heavy metal oxides which are hazardous to human health. Vanadium pentoxide, for example, is on the U.S. EPA's Extremely Hazardous Substances. In California, spent catalyst from SCR is considered to be hazardous waste and the volume of waste from SCR is large. The disposal of catalyst is expensive, but some catalyst manufacturers provide for disposal and/or recycling of the catalyst. In Japan, for example, titanium from titanium dioxide spent catalyst is used from paint pigment. An advantage of precious metal catalysts is that they do not produce as much hazardous waste, and they have a salvage value at the end of their useful life, but the initial cost is higher.

Ammonia is necessary for the chemical reactions in SCR to work. Unfortunately, ammonia is also a hazardous substance. Ammonia is on the U.S. EPA's list of extremely hazardous substances under Title III, Section 302 of the Superfund Amendments and Reauthorization Act of 1986 (SARA). Ammonia is immediately dangerous to life and health (IDLH) at only 500 ppm. It has a time weighted average (TWA) exposure limit (the maximum allowable exposure limit in a 10 hour day in a 40 hour week) of 25 ppm. Ammonia has a pungent, suffocating odor. Exposure to ammonia causes eye, nose, and throat irritation and it will burn the skin.

Ammonia is released from an SRC system because excess ammonia is required for efficient conversion of NOx to nitrogen. Excess ammonia is required because of imperfect distribution of the chemical. In theory, if the ammonia could be perfectly distributed so that the reactants could come into contact, no ammonia would be released, but in the real world this is not possible. This is also analogous to the necessity for excess air required for combustion. Excess air is required since all the oxygen molecules can't find all the fuel molecules to react with during the short period of time of combustion due to imperfect mixing of fuel and air. The molar ratio of nitrogen oxide (NO) to ammonia in the SCR reaction is 1.0 (i.e. 1 ft^3 of ammonia is required to convert 1 ft^3 of NOx), and the molar ration of ammonia to nitrogen dioxide (NO_2) is two. Over 80% of the NOx compounds in the exhaust are nitrogen oxide, so the SCR system is usually run with a ratio of ammonia to NOx around 1.0. Further increase of the ratio will reduce NOx emissions, but emissions of ammonia will increase.

In an SCR unit, it is critical that the ammonia is injected and thoroughly distributed throughout the flue gas stream. This is done with the ammonia injected grid located upstream of the catalyst. Ammonia is drawn out of a storage tank and evaporated with the electrical heated or steam heated vaporizer. The vapor is then mixed with a carrier gas which is usually compressed air or steam. The carrier gas provides the momentum to deliver the gas into the exhaust stream.

The storage of ammonia is usually considered to be a greater potential hazard than the ammonia slip from the stack. Emitted levels of ammonia slip are far below the odor and health hazard thresholds of the chemical. Since ammonia is water soluble, it doesn't remain very long in the atmosphere.

Ammonia from SCR is stored in a tank and a relatively large amount of storage is required. Accidental release from storage could pose problems to communities surrounding the ship. Aqueous and anhydrous ammonia are the two types of ammonia used for ammonia injection. The aqueous form is favored in that the stored ammonia concentration can be limited and the volatilization rate is reduced, so it is safer. The aqueous form is used in more heavily populated areas.

Urea is a chemical that comes in the form of powder that can also be used in place of ammonia for SCR. The urea is dissolved with water and then injected into the exhaust stream. The urea breaks down to form nitrogen and hydrogen compounds that will react with nitrogen oxide. The temperature range for efficient NOx reduction with urea is higher than the exhaust temperature of most engines, so urea injection is limited to systems where there is supplemental firing applied to the exhaust stream.

Shoreside Port Electrification ("Cold Ironing")

Supplying shore power to a vessel while at port is an option to reduce hotelling emissions. While shore power is supplied to the ship, the auxiliary engines are turned off. This option does not completely eliminate emissions because most vessels continue to operate boilers. However the emissions from boilers is a small fraction of the hotelling emissions from most vessels, so overall emissions are reduced dramatically. Table VII-5 below compares the emissions per unit of energy for a marine auxiliary engine operating on residual fuel (heavy fuel oil) and distillate fuel (marine diesel oil), and for a power plant.

Table VII-5: Auxiliary Engine and Powerplant Emission Comparison

Pollutant	Residual (g/kw-hr)	MDO (g/kw-hr)	Powerplant (g/kw-hr)
NOx	14.7	13.9	0.0908
PM	1.5	0.3	0.012
SOx	12.3	1.1	0.006

Source: ARB, 2004

As stated previously, shoreside power eliminates the emissions from vessel auxiliary engines, but the power is produced by powerplants. Powerplants get their power from a variety of sources each with a variety of air emissions. Natural gas plays a dominant role in California's fuel-fired generating system and is the preferred fuel for powerplants because of its cleaner combustion characteristics compared to other fuels. Natural gas has negligible sulfur, which limits sulfur compound emissions; negligible ash, which limits particulate matter emissions; and NOx emission rates that are generally lower than from other fuel types. Natural gas provides 91 percent of the fuel – fired electrical generation in California. (ARB, 2004)

Diesel Oxidation Catalyst (DOC)

Two potential adverse environmental impacts from the use of DOCs have been identified. First, as is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and sulfur content of the fuel, the increase in sulfate particles may offset the reductions in soluble organic fraction emissions. Using low sulfur diesel fuel can minimize this effect. Second, a DOC could be considered a "hazardous waste" at the end of its useful life depending on the materials used in the catalytic coating. Because catalytic converters have been used on gasoline powered on-road vehicles for many years, there is a very well-established market for these items (see, for example, http://www.pacific.recycle.net – an Internet posting of buyers and sellers of various scrap materials). In the recycling process, the converters are broken down, and the metal is added to the scrap-metal stream for recycling, while the catalysts (one or a combination of the platinum group metals) are extracted and reused.

Because of platinum's high activity as an oxidation catalyst, it is the predominant platinum group metal used in the production of DOC. There is a very active market for reclaimed platinum for use in new catalytic converters, jewelry, fuel cells, cathode ray tube screens, catalysts used during petroleum refining operations, dental alloys, oxygen sensors, platinum electrode spark plugs, medical equipment, and platinum-based drugs for cancer treatment, to name a few. (Kendall, 2002) (Kendall, 2003)

Catalyzed Diesel Particulate Filters

These devices are composed of a ceramic diesel particulate filter along with a platinum catalyst to catalyze the oxidation of carbon-containing emissions and significantly reduce diesel PM emissions. This is an obvious positive environmental impact.

However, there are also inorganic solid particles present in diesel exhaust, which are captured by diesel particulate filters. These inorganic materials are metals derived from engine oil, diesel fuel, or engine wear and tear. While the PM filter is capable of capturing inorganic materials, these materials are not oxidized into a gaseous form and expelled.

Because these materials would otherwise be released into the air, the filters are benefiting the environment by capturing these metallic particles, known as "ash." However, the ash that is collected in the PM filter must be removed from the filter periodically to maintain the filter's effectiveness.

Ash collected from a diesel engine using a typical lubrication oil and no fuel additives has been analyzed and is primarily composed of oxides of the following elements: calcium, zinc, phosphorus, silicon, sulfur, and iron. Zinc is the element of primary concern because, if present in high enough concentration, it can make a waste a hazardous waste. Title 22, CCR, section 66261.24 establishes two limits for zinc in a waste: 250 milligrams per liter for the Soluble Threshold Limit Concentration and 5,000 milligrams per kilogram for the Total Threshold Limit Concentration. The presence of zinc at or above these levels would cause a sample of ash to be characterized as a hazardous waste.

Under California law, it is the generator's responsibility to determine whether their waste is hazardous or not. Applicable hazardous waste laws are found in the H&SC, division 20; title 22, CCR, division 4.5; and title 40 of the Code of Federal Regulations. Staff recommends owners that install a diesel particulate filter on an engine to contact both the manufacturer of the diesel emission control system and the California Department of Toxic Substances Control (DTSC) for advice on proper waste management.

The ARB staff has consulted with personnel of the DTSC regarding management of the ash from diesel particulate filters. DTSC personnel have advised ARB that it has a list of facilities that accept waste from businesses that qualify as a conditionally exempt small quantity generator. Such a business can dispose of a specific quantify of hazardous waste at certain Household Hazardous Waste events, usually for a small fee. An owner who does not know whether or not he qualifies or who needs specific information regarding the identification and acceptable disposal methods for this waste should contact the DTSC.[6]

Additionally, the technology exists to reclaim zinc from waste. For example, the Swedish company MEAB has developed processes for extracting zinc and cadmium from various effluents and industrial waste streams. Whether reclamation for reuse will be economically beneficial remains to be seen. (MEAB, 2003)

Because of the time and costs associated with filter maintenance, there are also efforts by industry to reduce the amount of ash formed. Most of the ash is formed from the inorganic materials in engine oil, particularly from zinc-containing additives necessary to control acidification of engine oil – due in part to sulfuric acid derived from sulfur in diesel fuel. As the sulfur content of diesel fuel is decreased, the need for acid neutralizing additives in engine oil should also decrease. A number of technical programs are ongoing to determine the impact of changes in oil ash content and other

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[6] Information can be obtained from local duty officers and from the DTSC web site at http://www.dtsc.ca.gov.

characteristics of engine oil on exhaust emission control technologies and engine wear and performance.

It may also be possible to reduce the ash level in diesel exhaust by reducing oil consumption from diesel engines. Diesel engine manufacturers over the years have reduced engine oil consumption in order to reduce PM emissions and to reduce operating costs for engine owners. Further improvements in oil consumption may be possible in order to reduce ash accumulation rates in diesel particulate filters.

In addition, measurements of NOx emissions for heavy-duty diesel vehicles equipped with passive catalyzed filters have shown an increase in the NO_2 portion of total NOx emissions, although the total NOx emissions remain approximately the same. In some applications, passive catalyzed filters can promote the conversion of NO emissions to NO_2 during filter regeneration. More NO_2 is created than is actually being used in the regeneration process; and the excess is emitted. The NO_2 to NOx ratios could range from 20 to 70 percent, depending on factors such as the diesel particulate filter systems, the sulfur level in the diesel fuel, and the duty cycle. (DaMassa, 2002)

Formation of NO_2 is a concern because it irritates the lungs and lowers resistance to respiratory infections. Individuals with respiratory problems, such as asthma, are more susceptible to the effects. In young children, nitrogen dioxide may also impair lung development. In addition, a higher NO_2/NOx ratio in the exhaust could potentially result in higher initial NO2 concentrations in the atmosphere which, in turn, could result in higher ozone concentrations.

Model simulations have shown that a NO_2 to NO_X emission ratio of approximately 20 percent would nearly eliminate any impact of increased NO_2 emissions. (DaMassa, 2002). According to the model, at the NO_2 to NOx ratio of 20 percent, there will be a decrease of the 24-hour ozone exposure (greater than 90 parts per billion) by two percent while an increase of the peak 1-hour NO_2 by six percent (which is still within the NO_2 standard).

The health benefits derived from the use of PM filters are immediate and offset the possible adverse effects of increases in NO_2 emissions. For this reason, a cap of 20 percent NO_2 to NOx emission ratio was established for all diesel emission control systems through ARB's Verification Procedure.

E. Reasonably Foreseeable Mitigation Measures

The ARB staff has concluded that no significant adverse environmental impacts should occur from adoption of and compliance with the proposed regulation. Therefore, no mitigation measures would be necessary.

F. Reasonably Foreseeable Alternative Means of Compliance with the Proposed Regulation

Alternatives to the proposed regulation are discussed in Chapter V of this report. ARB staff has concluded that the proposed regulation provides the most effective and least burdensome approach to reducing children's and the general public's exposure to diesel PM and other air pollutants emitted from oceangoing auxiliary diesel-fueled engines.

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